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(54) Automatic electricity meter reading system

(57) An automatic electricity meter reading system consists of a large number of electricity meter readers, a small number of meter data receivers, a multiplexer and a computer. Each electricity meter reader reads a plurality of electricity meters belonging to different customers in the neighbourhood and at a specified time makes a telephone call and transmits meter data to a meter data receiver installed at an electricity control centre, and at the same time also receives control data including the time at which the next call is to be made from the meter data receiver. The meter data is then transmitted daily from the meter data receivers through a multiplexer to a computer installed at the same location for storage, billing and other processing. All meter readers are A.C. power operated.

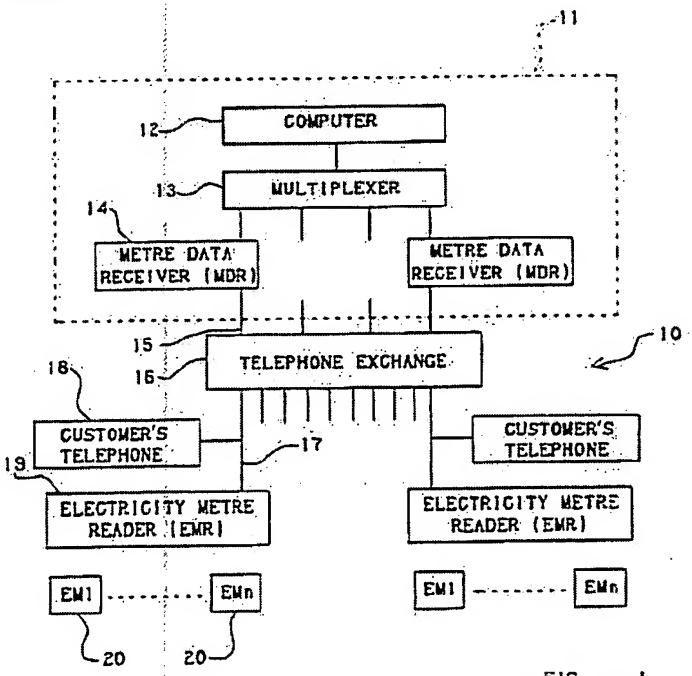


FIG 1

GB 2 284 961 A

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

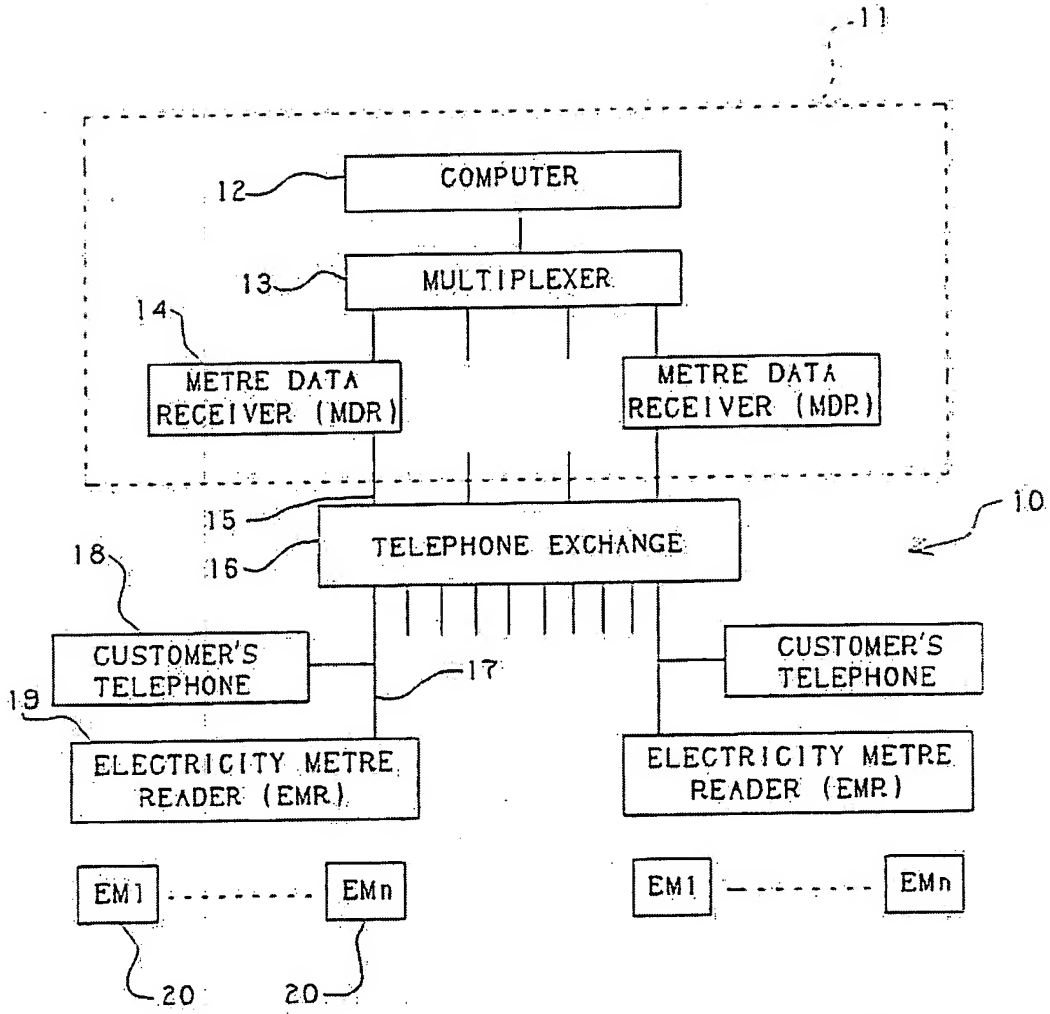

11
12
COMPUTER
13
MULTIPLEXER
14
METRE DATA RECEIVER (MDR)
METRE DATA RECEIVER (MDR)
15
16
TELEPHONE EXCHANGE
10
18
CUSTOMER'S TELEPHONE
17
CUSTOMER'S TELEPHONE
19
ELECTRICITY METRE READER (EMR)
ELECTRICITY METRE READER (EMR)
EM1
EMn
EM1
EMn
20
20

FIG 1

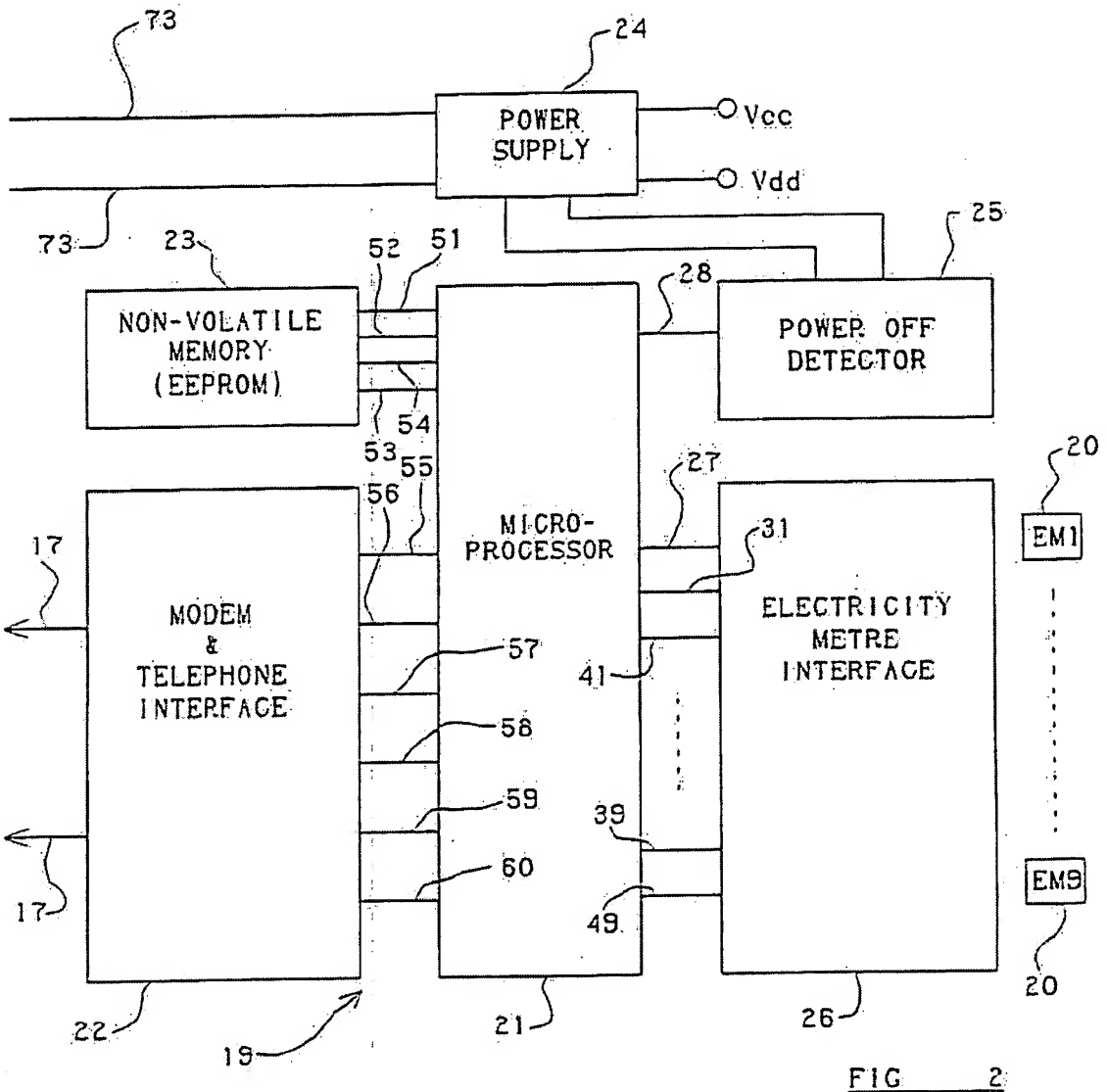


FIG 2

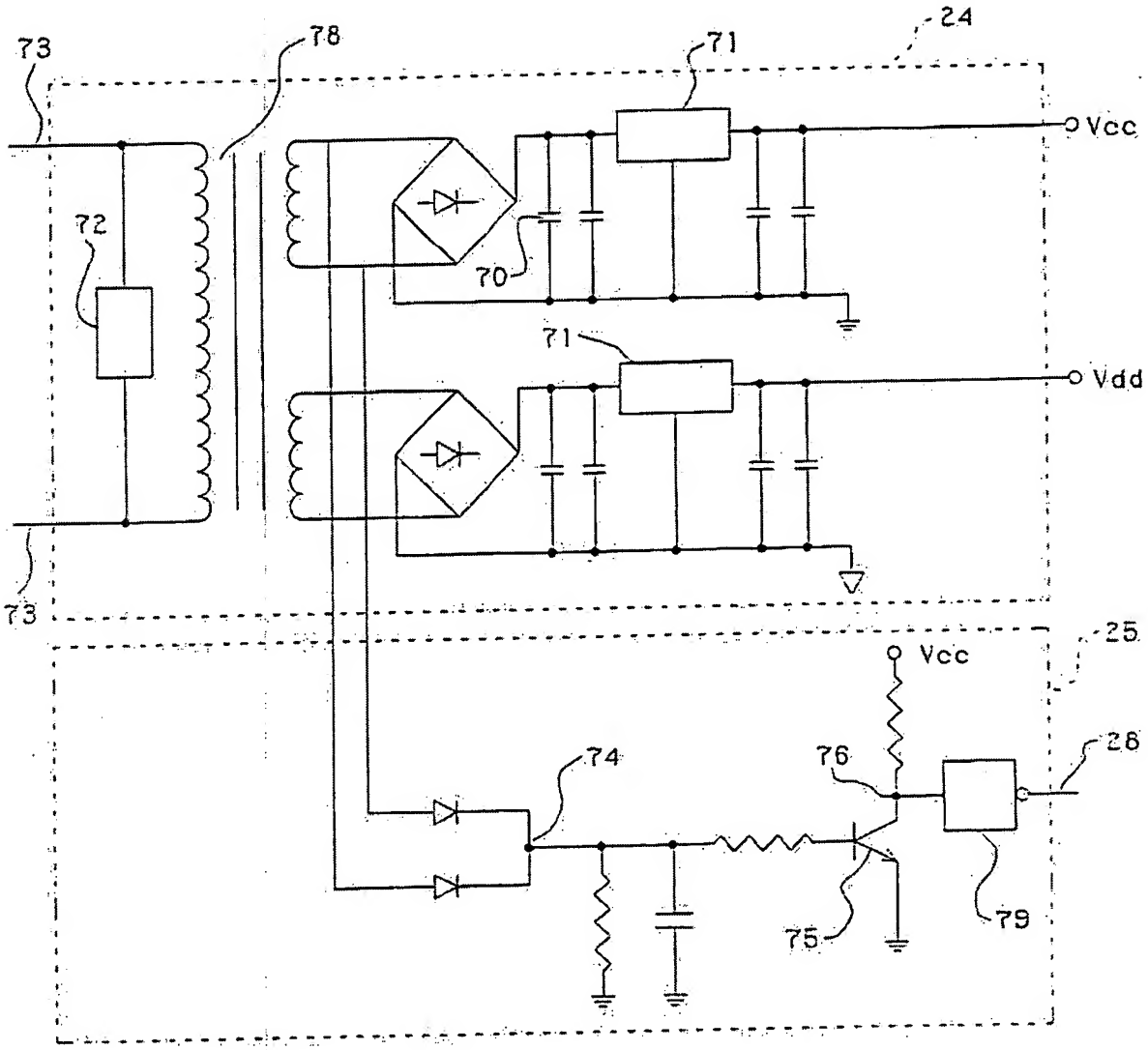


FIG 3

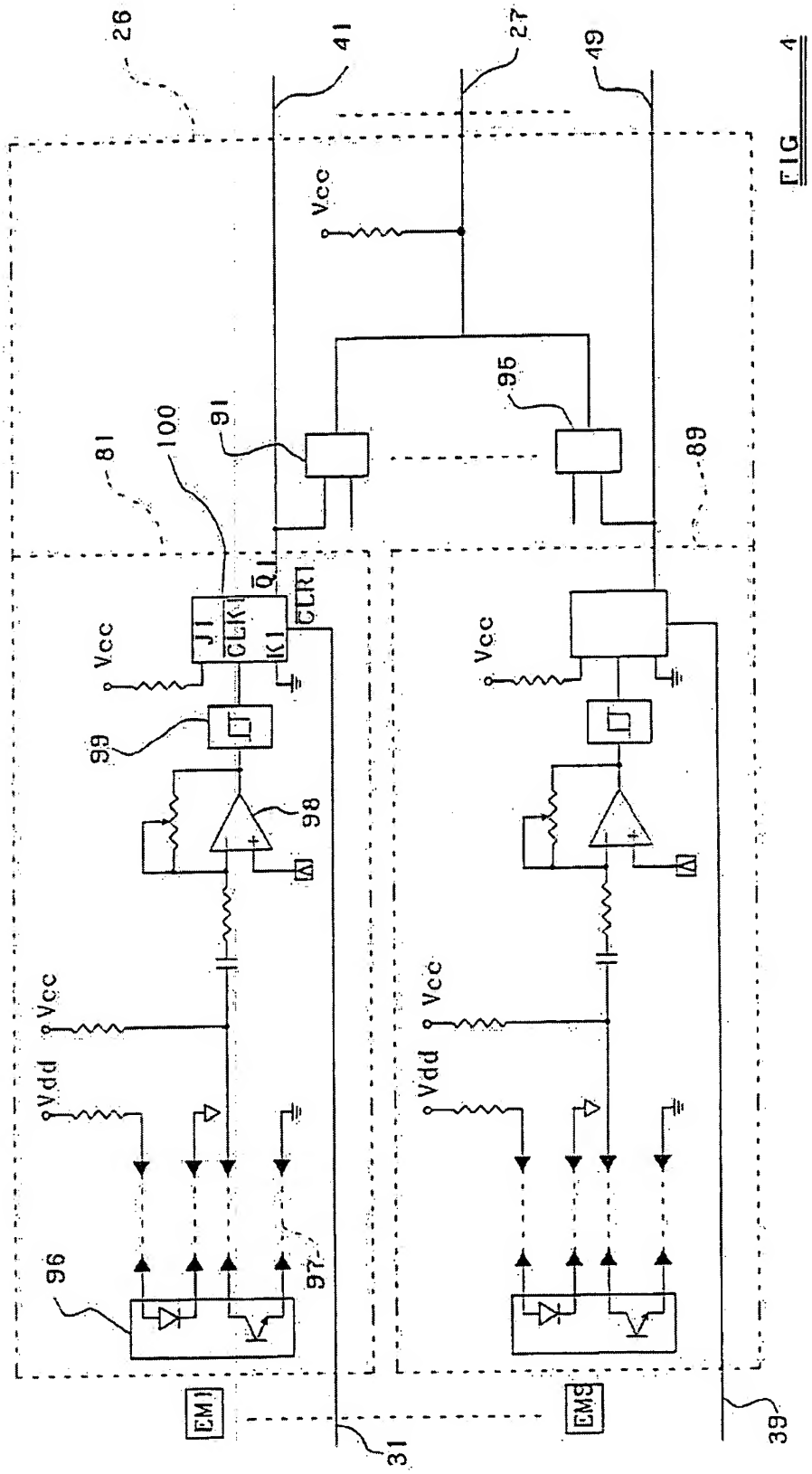
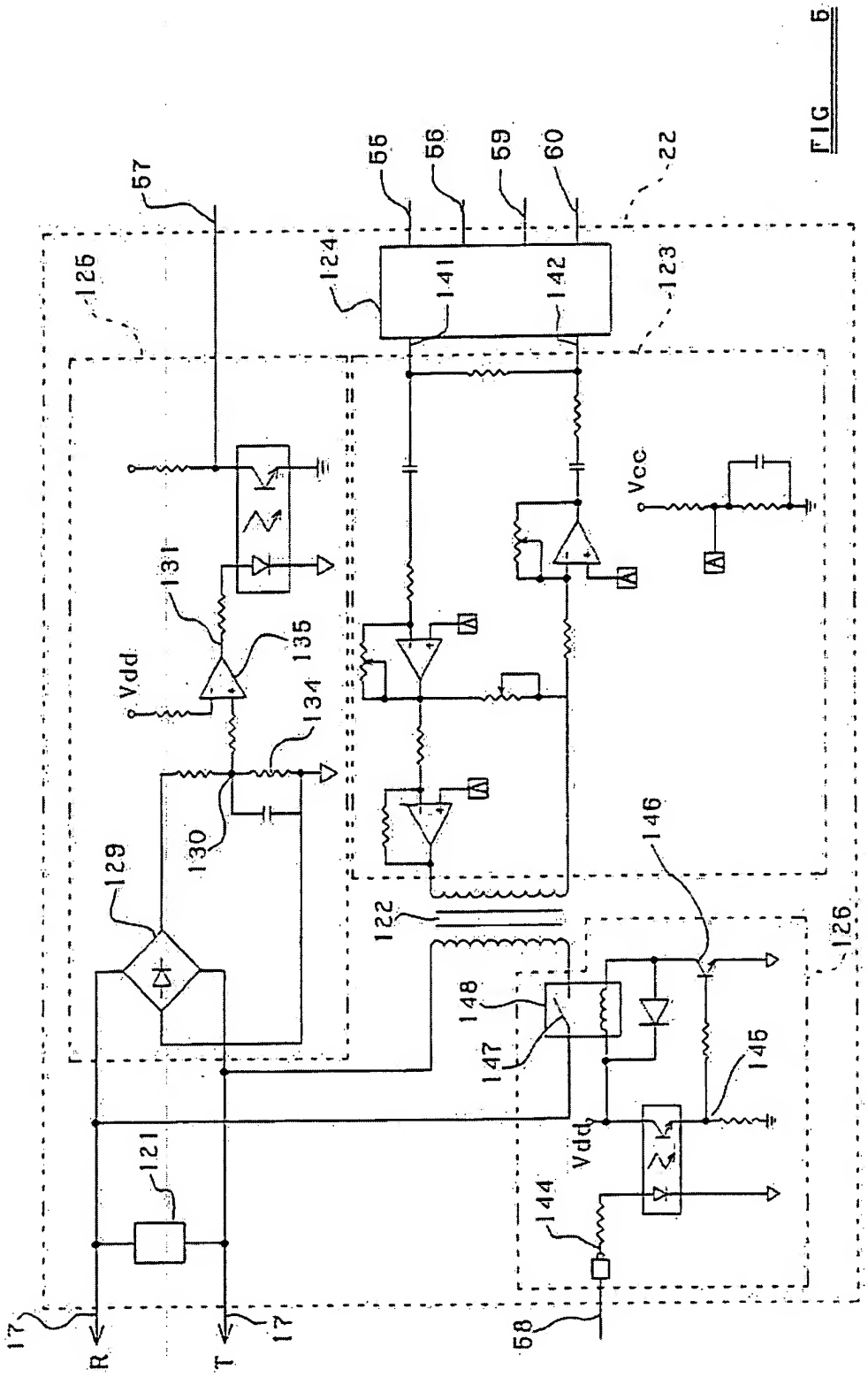


FIG 4

FIG 5


57
55
56
59
60
22
126
124
141
142
123
Vcc
131
135
Vdd
134
130
129
146
122
126
148
147
145
Vdd
144
121
17
R
T
17
58

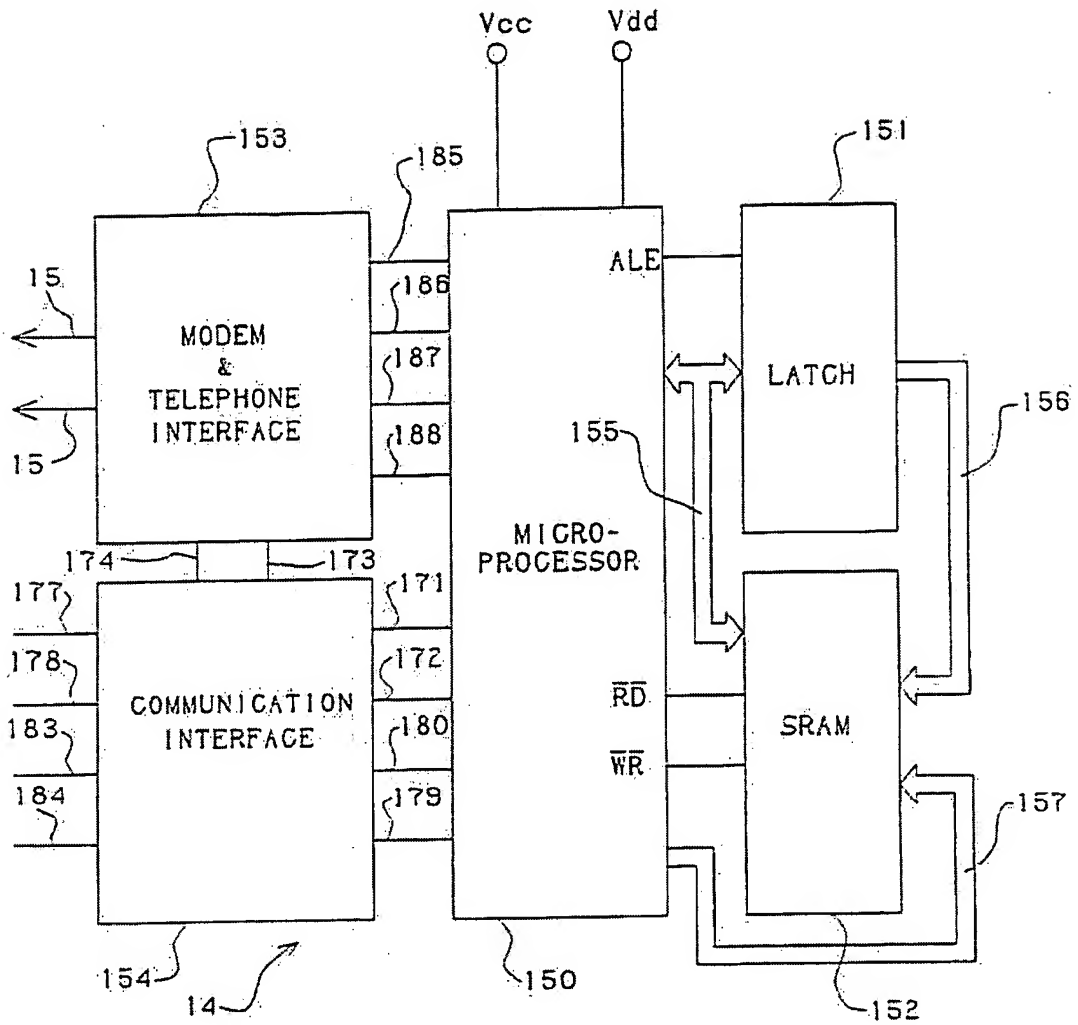
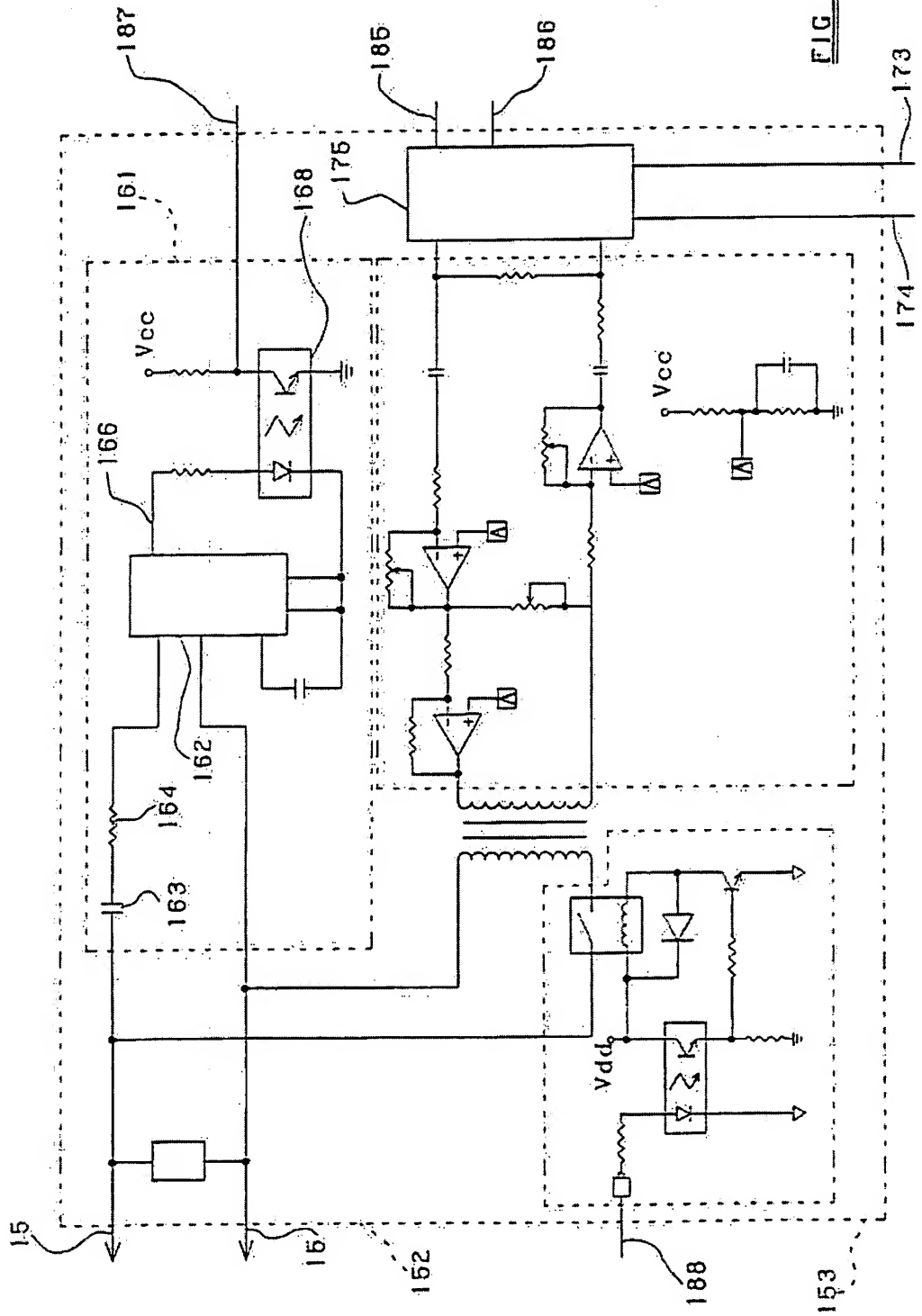


FIG 6

FIG 7


187
185
186
173
175
161
168
174
Vcc
166
Vcc
162
164
163
Vdd
15
16
152
188
153

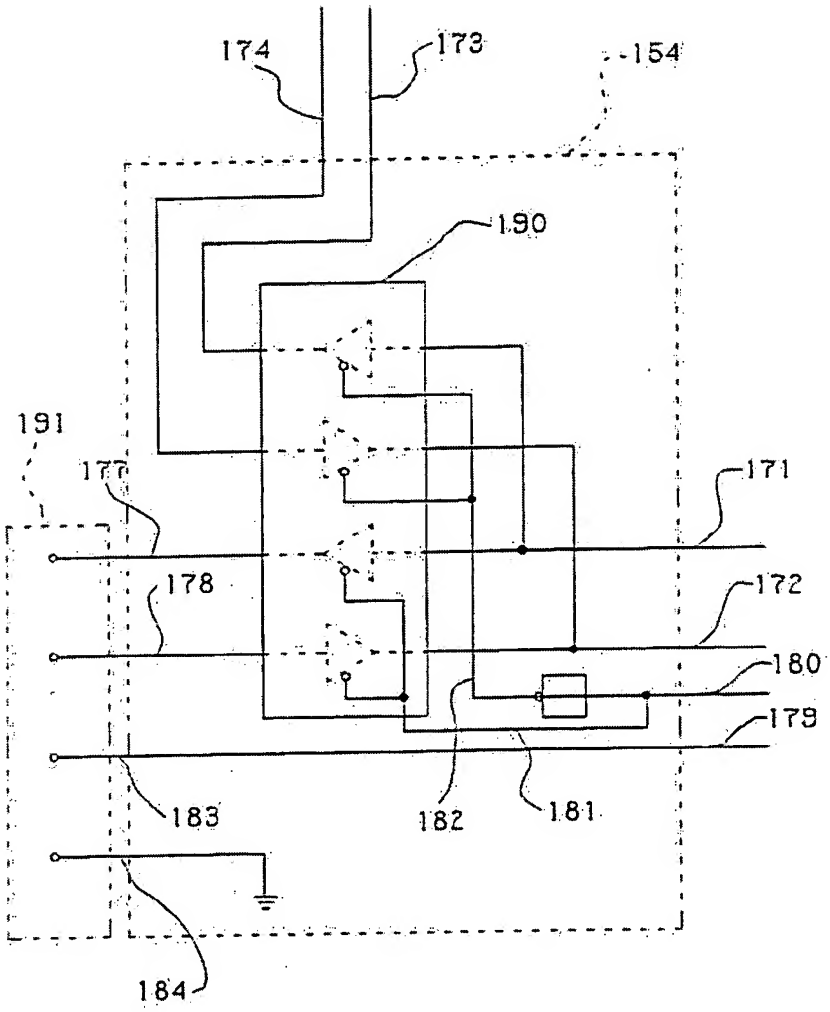


FIG 8

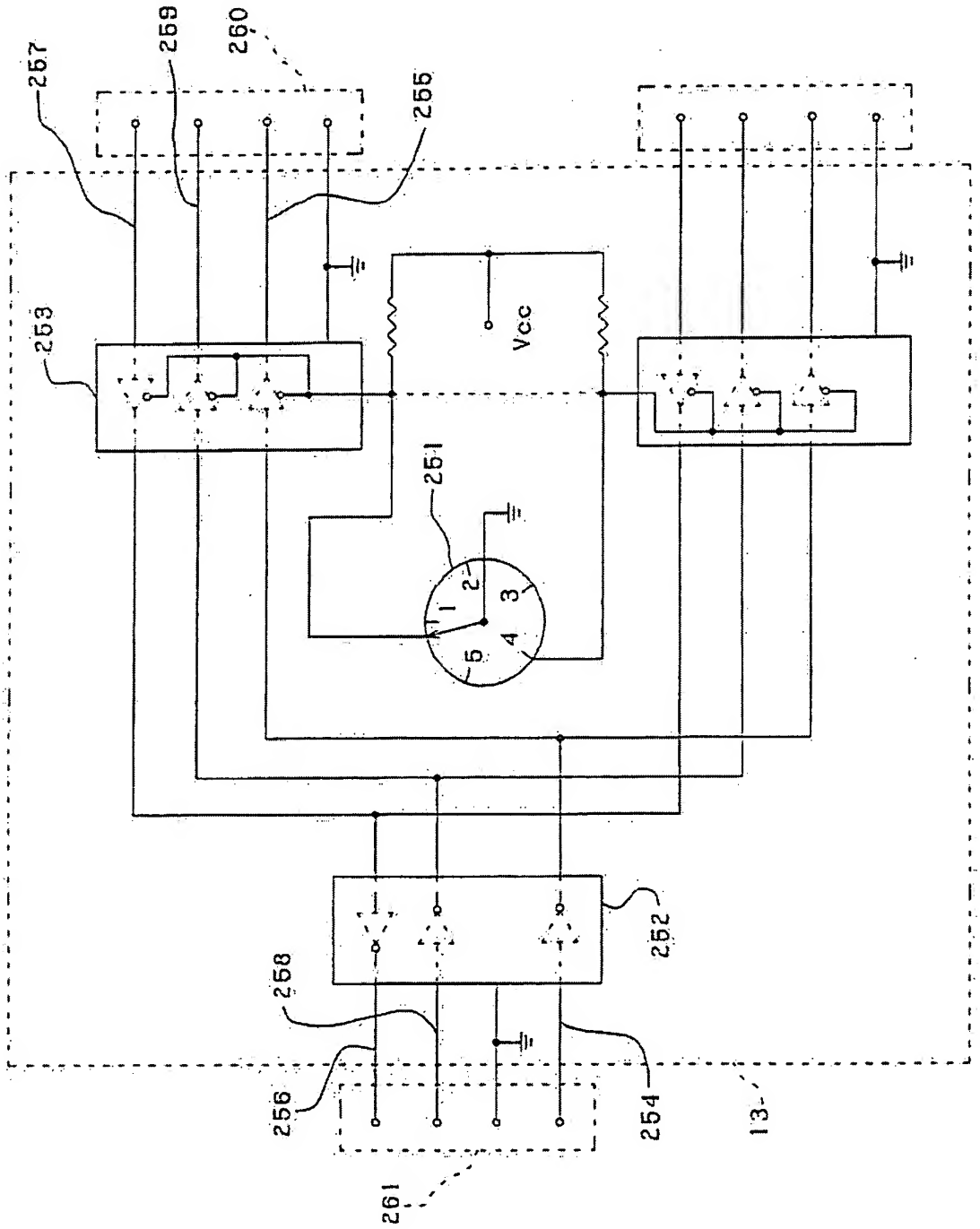
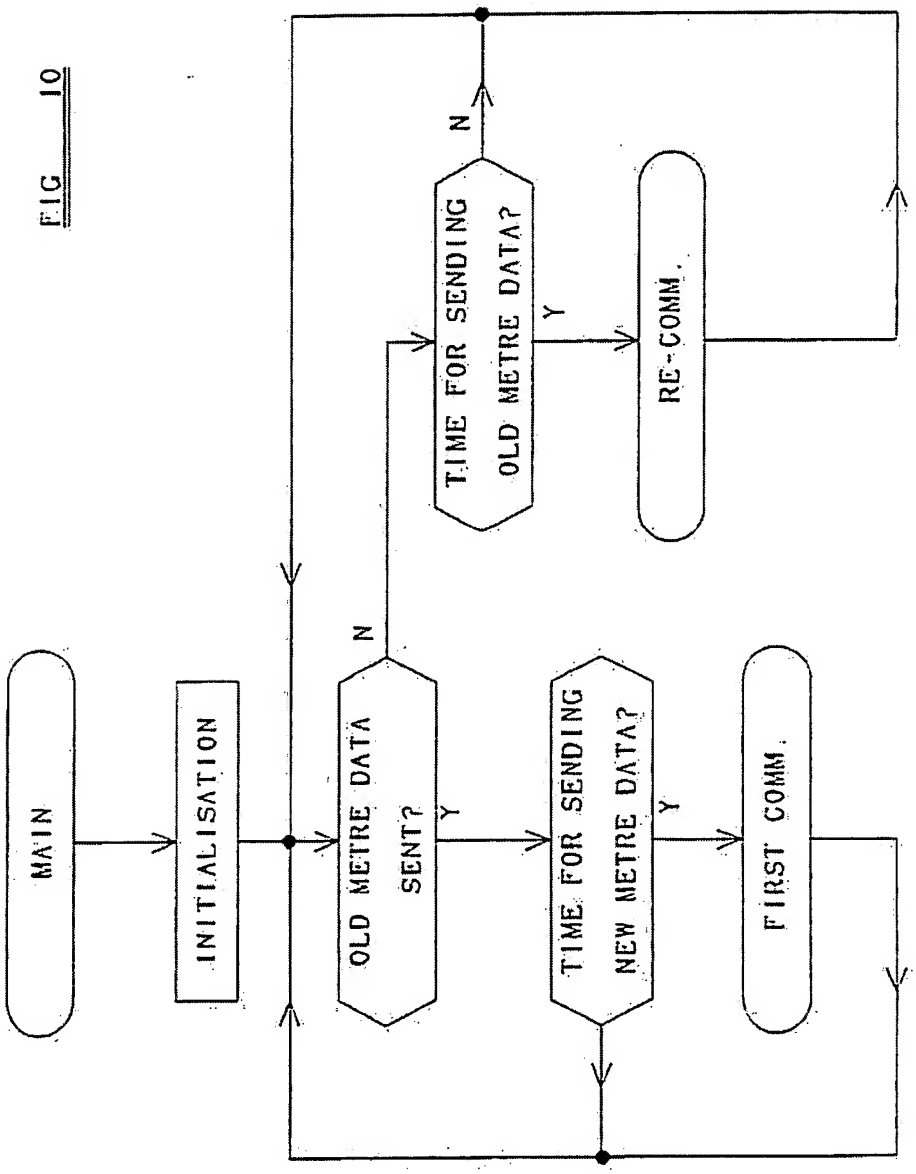


FIG 9

FIG 10



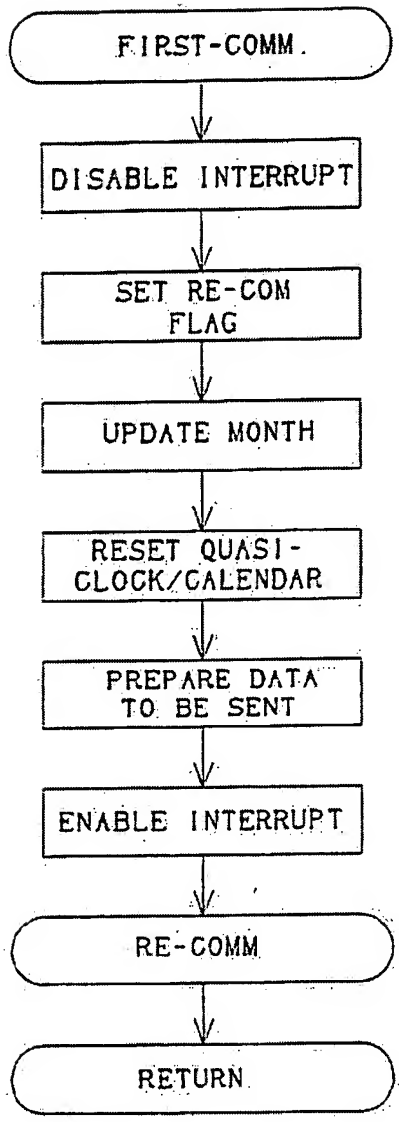

FIRST-COMM.
DISABLE INTERRUPT
SET RE-COM FLAG
UPDATE MONTH
RESET QUASI-CLOCK/CALENDAR
PREPARE DATA TO BE SENT
ENABLE INTERRUPT
RE-COMM
RETURN

FIG 11

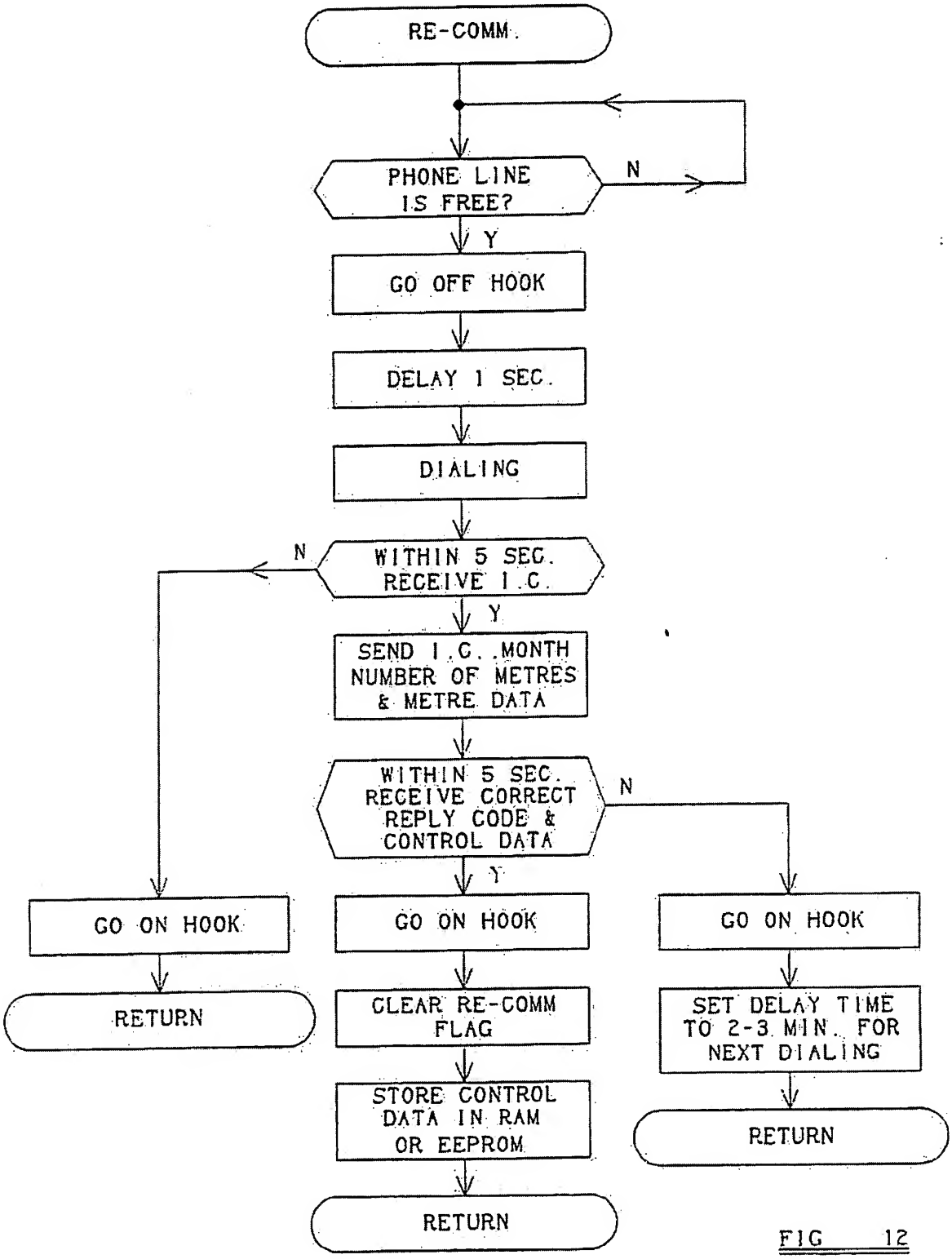


FIG 12

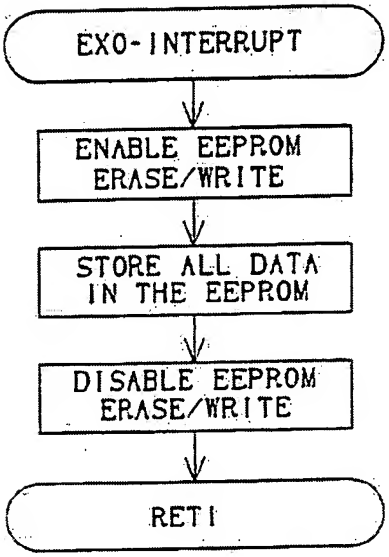

EX0-INTERRUPT
ENABLE EEPROM ERASE/WRITE
STORE ALL DATA IN THE EEPROM
DISABLE EEPROM ERASE/WRITE
RETI

FIG 13

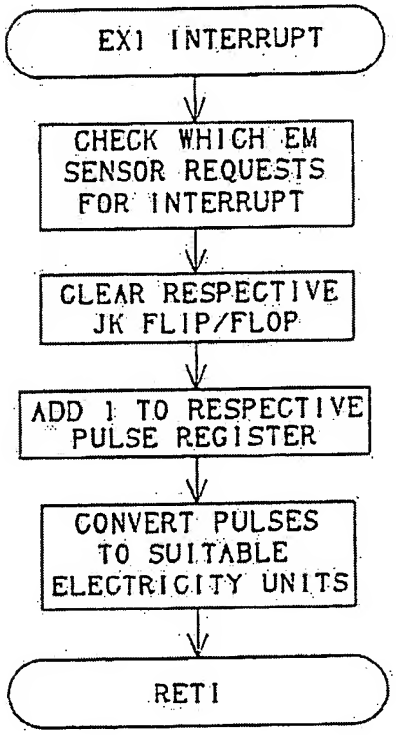

EX1 INTERRUPT
CHECK WHICH EM SENSOR REQUESTS FOR INTERRUPT
CLEAR RESPECTIVE JK FLIP/FLOP
ADD 1 TO RESPECTIVE PULSE REGISTER
CONVERT PULSES TO SUITABLE ELECTRICITY UNITS
RETI

FIG 14

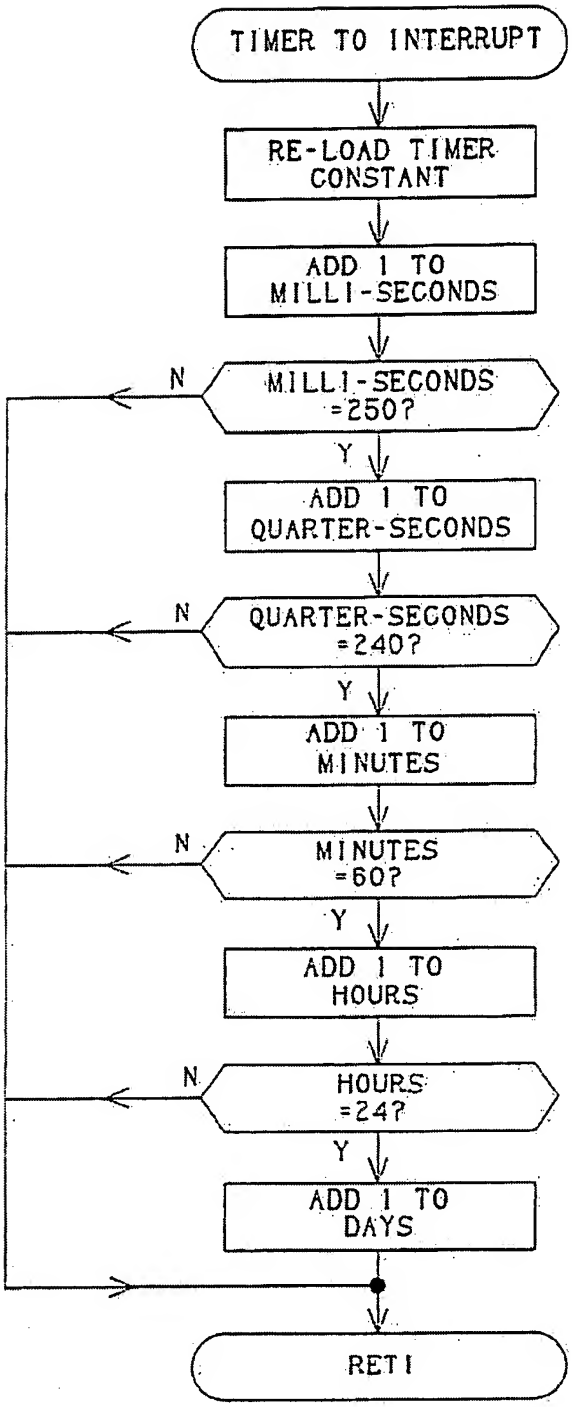


FIG 15

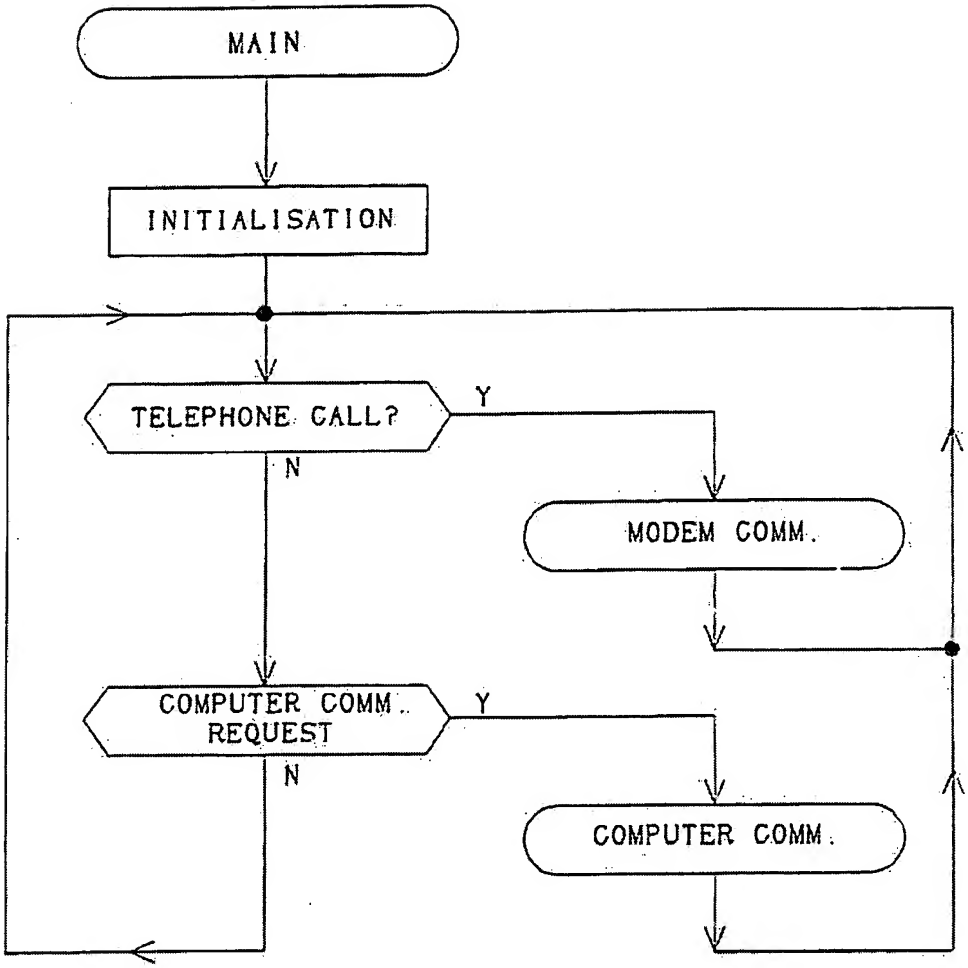

MAIN
INITIALISATION
TELEPHONE CALL?
Y
N
MODEM COMM.
COMPUTER COMM. REQUEST
Y
N
COMPUTER COMM.

FIG 16

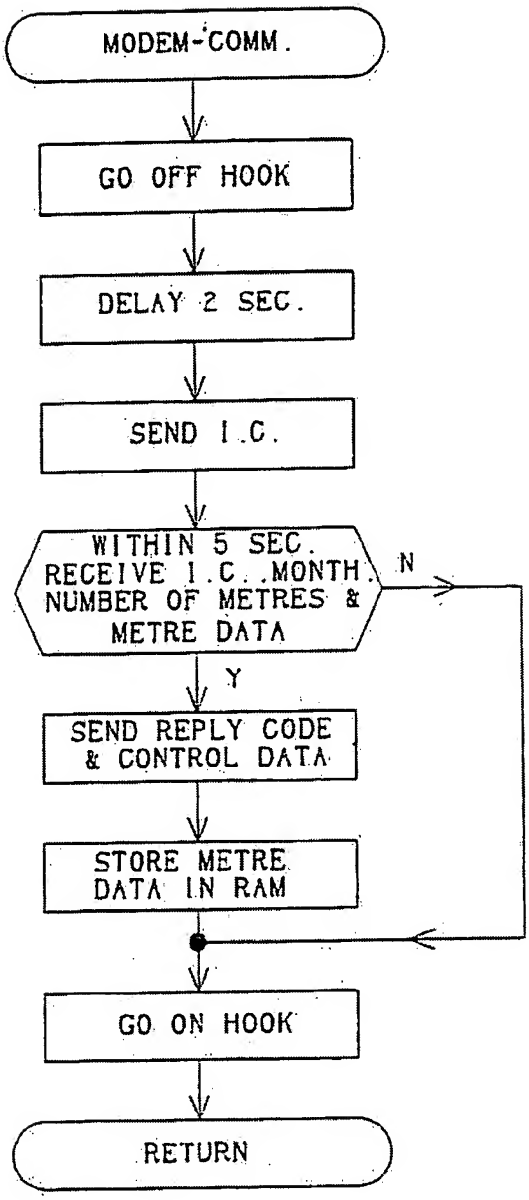

MODEM-COMM.
GO OFF HOOK
DELAY 2 SEC.
SEND I.C.
WITHIN 5 SEC. RECEIVE I.C. MONTH. NUMBER OF METRES & METRE DATA
N
Y
SEND REPLY CODE & CONTROL DATA
STORE METRE DATA IN RAM
GO ON HOOK
RETURN

FIG 17

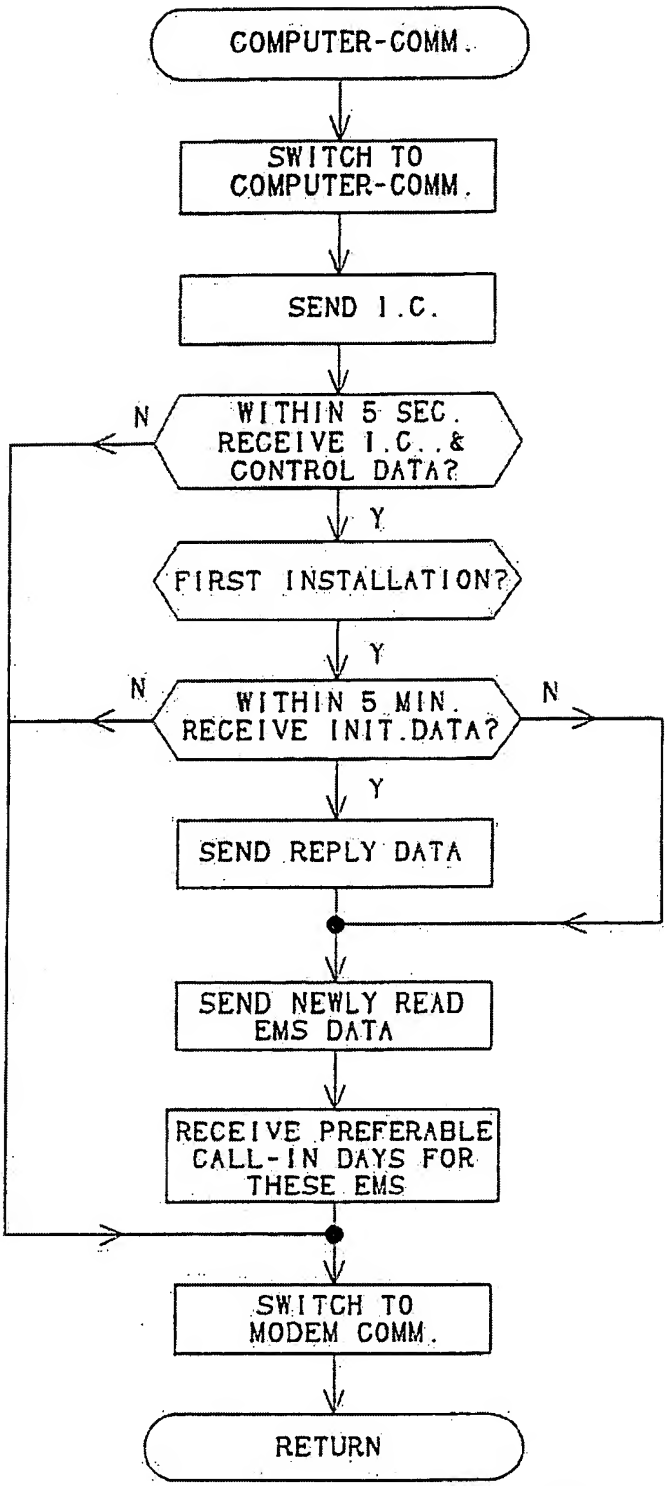

COMPUTER-COMM.
SWITCH TO COMPUTER-COMM.
SEND I.C.
WITHIN 5 SEC. RECEIVE I.C. & CONTROL DATA?
N
Y
FIRST INSTALLATION?
Y
WITHIN 5 MIN. RECEIVE INIT.DATA?
N
N
Y
SEND REPLY DATA
SEND NEWLY READ EMS DATA
RECEIVE PREFERABLE CALL-IN DAYS FOR THESE EMS
SWITCH TO MODEM COMM.
RETURN

FIG 18

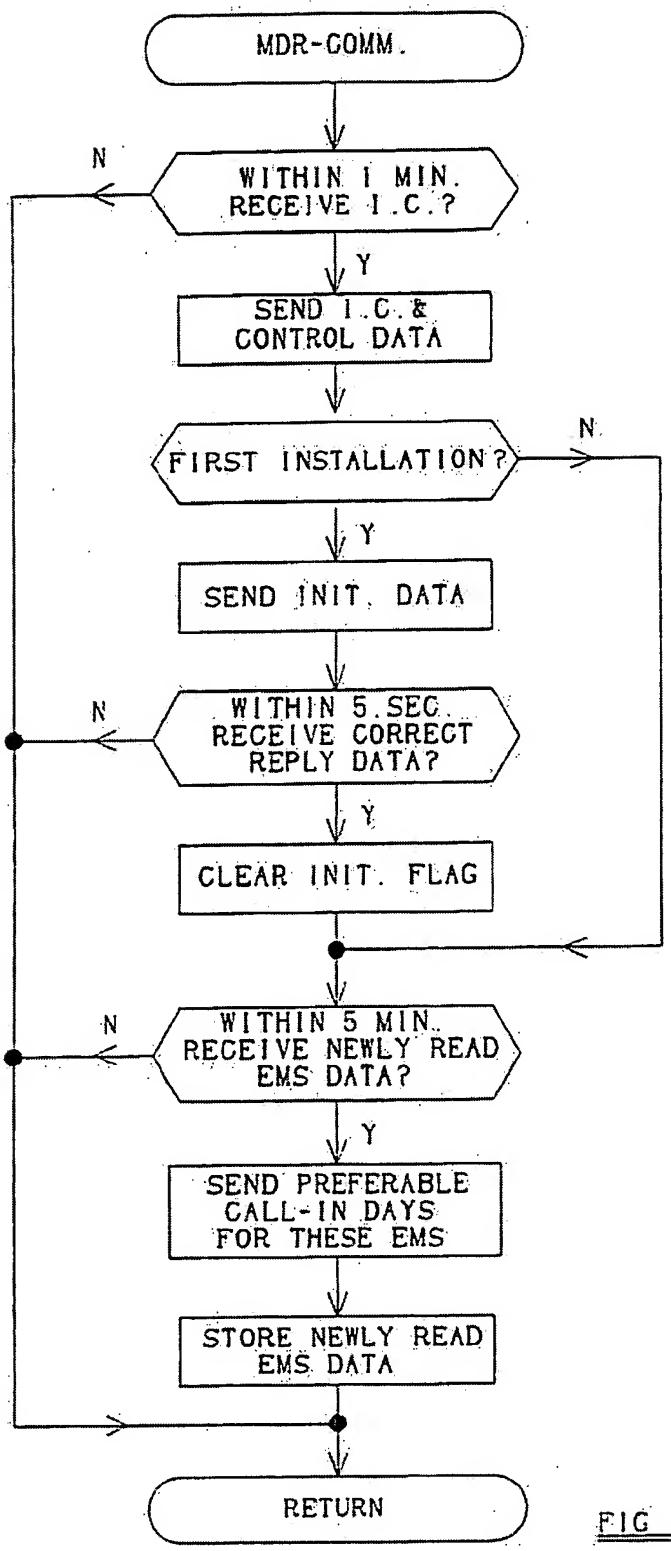


FIG 19

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PATENTS ACT 1977

P8771GB-ALM/LH/vb

"Automatic Meter Reading System"

The present invention relates to an automatic meter reading system.

There have been several prior art proposals for different automatic meter reading systems using customers' telephone lines. There are basically two types of such systems. In the first type of system, a command call is issued periodically from a central control station to a meter reader linked to a single customer's telephone line and attached to the customer's utility meter. Upon receiving the command call, the meter reader sends the meter data read within one period to the central control station for the purpose of storage, billing and other processing. However, such systems may ring the customer's telephone (US-A-4 856 054) or require installation of special equipment either at the customer's location (US-A-4 394 540) or at the telephone exchange (US-A-4 540 849).

In the second type of system, each meter reader is programmed to make a telephone call and to transmit periodically the reading of the attached utility meter through a customer's telephone line to a data receiver in a utility control centre. The meter data is then transmitted regularly from the meter data receivers to a computer at the same location for the purpose of storage, billing and other processing. In this type of system, periodical command calls from the utility control centre to the meter readers are not required, but occasional command calls to a meter reader may still be needed when a meter reader is first installed or when the owner has changed.

Such a system is disclosed in International Patent Application No. WO 87/07993. Other proposals for such a system are disclosed in US-A-4 287 567, US-A-4 388 690, US-A-4 455 453 and US-A-4 578 536.

None of the above mentioned automatic meter reading systems have yet been widely adopted in practice.

Conventional automatic meter reading systems employ one automatic meter reader for obtaining a meter reading from a single customer. This arrangement is natural for regions where most of the residential and business premises are separated from one another but it would require an extremely large number of meter readers to be installed as a local utility company would normally have several hundred thousand or even a few million residential and business customers. The high cost of implementing known automatic meter reading systems is believed to be the primary reason why such systems are not widely accepted in practice. Another disadvantage of providing one meter reader for one customer is that a utility company may hesitate to install such a system if customers who live in widely scattered locations do not have their own telephone lines, and will not be able to make use of the system.

Another reason why known meter reading systems are not widely used is that the means for sensing a utility meter is either incomplete or inconvenient to implement in practice. For example, to install the meter reader proposed in US-A-4 578 536 or in US-A-4 856 054 it is necessary to modify the associated conventional utility meter such as by opening the case of the meter and connecting certain electronic components to the interior of the meter. Such modification is time consuming and could also affect the accuracy of the meter. Additionally, the

utility company may well object to such tampering with their meters. In the metering system proposed in International Patent Application No. WO 87/07993, it is assumed that electric pulses representing utility meter data have already been available for an automatic meter reader, and no means has been provided or mentioned for converting meter data to electric pulses. It is believed that how to sense a utility meter reading is an important problem of an automatic meter reading system, and any proposals for a practical automatic meter reading system must provide an explicit and satisfactory solution to this problem.

A further factor which might affect the applicability of an automatic meter reading system is the requirement of an automatic meter reader to be battery-operated. The need to change batteries from time to time for battery-operated meter readers is costly, inconvenient and insecure.

Accordingly, in accordance with one aspect of the present invention there is provided an automatic meter reading system comprising: a plurality of electricity meter readers, each of which is linked to a customer's telephone line, is able to read a plurality of electricity meters belonging to different customers in the neighbourhood, and is able to make a phone call and transmits periodically the meter reading to a remote meter data receiver, and to receive a next calling time from a remote meter data receiver during this telephone communication; one or more meter data receivers, each of which is able to receive a phone call and meter data from those associated electricity meter readers, and is able to transmit the received meter data daily to a computer through a multiplexer; a multiplexer which provides an interface between a computer

and the meter data receivers; a computer which is able to receive meter data daily from one or more meter data receivers, and is able to store these data for the purpose of billing, printing and other processing.

Another aspect of the present invention provides an automatic meter reading system for reading a plurality of meters comprising: a plurality of meter readers, each meter reader being provided with means for communicating via a single communication line with a control centre and means for sensing the meter readings of a set of the plurality of meters, the data read from the set of meters being communicated via the meter reader to the control centre.

One embodiment of the present invention seeks to provide an automatic electricity meter reading system, which possesses the features of extreme cost effectiveness, good performance, high reliability, minimal maintenance, easy installation, simple operation, without modification of electricity meters and with least interference to both customers and electricity meter readers.

Another embodiment of the present invention provides an automatic electricity meter reading system which is extremely cost effective. Specifically, each electricity meter reader is able to read a plurality of (up to several dozens) electricity meters belonging to different customers in the neighbourhood, while using only one customer's telephone line for the transmission of these electricity meters data to a meter data receiver installed at an electricity control centre.

One embodiment of the present invention provides a system in which every electricity meter reader does not require a battery to operate, and once installed, each

electricity meter reader can be sealed for at least ten years to minimise maintenance services.

A further embodiment of the present invention provides a simple and reliable means for sensing electricity meter readings. The installation of such an electricity meter reader does not affect the accuracy or normal operation of the electricity meter.

Embodiments of the invention seek to provide a system in which every electricity meter reader contains a microprocessor whose functions are fully exploited to minimise the number of peripheral electronic components used. This helps to reduce the cost of an electricity meter reader, and hence the overall cost of the proposed system.

One embodiment of the present invention provides a system in which none of the electricity meter readers need to receive any phone call from an electricity control centre, thus minimising potential interference both to customers and to electricity meter readers. This also helps to reduce the cost of the proposed system because ring detecting circuits are no longer required for the electricity meter readers. Additionally, such an embodiment does not require the additional circuitry associated with a ring detector.

In order that the present invention may be more readily understood, embodiments thereof will now be described, by way of example, with reference to the accompany drawings, in which:

Figure 1 is a schematic block diagram of an automatic electricity meter reading system embodying the present invention;

Figure 2 is a schematic block diagram of a preferred embodiment of an automatic electricity meter reader of the system of Figure 1;

Figure 3 is a schematic circuit diagram of a power supply and power off detector of the automatic electricity meter reader of Figure 2;

Figure 4 is a schematic circuit diagram of electricity meter interface circuitry of the automatic electricity meter reader of Figure 2;

Figure 5 is a schematic circuit diagram of modem and telephone interface circuitry of the automatic electricity meter reader of Figure 2;

Figure 6 is a schematic block diagram of a meter data receiver of the system of Figure 1;

Figure 7 is a schematic circuit diagram of modem and telephone interface circuitry of the meter data receiver of Figure 6;

Figure 8 is a schematic circuit diagram of communication interface circuitry of the meter data receiver of Figure 6;

Figure 9 is a schematic circuit diagram of a multiplexer of the system of Figure 1;

Figure 10 is a flow chart showing the operation of a microprocessor of an electricity meter reader in an electricity meter reading system embodying the present invention;

Figure 11 is a flow chart showing the operation of a microprocessor of an electricity meter reader when it is time to send the new electricity meter data;

Figure 12 is a flow chart showing the operation of the microprocessor of an electricity meter reader when it is going to send the new or old electricity meter data;

Figure 13 is a flow chart showing the operation of the microprocessor of an electricity meter reader when A.C. power is off;

Figure 14 is a flow chart showing the operation of the microprocessor of an electricity meter reader when one of the electricity meter sensors requests for interruption services;

Figure 15 is a flow chart showing the operation of the microprocessor of an electricity meter reader when it provides a software clock/calendar service by using its internal timer TØ;

Figure 16 is a flow chart showing the operation of the microprocessor of a meter data receiver;

Figure 17 is a flow chart showing the operation of the microprocessor of a meter data receiver when it detects a telephone call;

Figure 18 is a flow chart showing the operation of the microprocessor of a meter data receiver when it responds to the computer for communication.

Figure 19 is a flow chart showing the operation of the computer when it is communicating with a meter data receiver.

Briefly described, there is provided an automatic electricity meter reading system in which every electricity meter reader is connected to a single customer's telephone line. The chosen customers are those owning phone lines. Once installed, each electricity meter reader senses constantly a plurality of electricity meters in the neighbourhood, including those belonging to other customers who may not have telephone lines. Periodically, typically once every month at a day close to a pre-set day, an electricity meter reader makes a telephone call and transmits the meter data of the associated electricity meters through a single customer's telephone line to a meter data receiver installed at an electricity control centre, and at the same time, also receives control data from the meter data receiver, including the next calling time and occasionally, a new telephone number to call next time. The newly read electricity meter data is transmitted daily from the meter data receivers through a multiplexer to a computer installed at the same location for the purpose of storage, billing and other processing.

An important feature of this invention is the recognition of the need for an automatic electricity meter reading system in which one electricity meter reader is able to read a plurality of electricity meters belonging to different customers in the neighbourhood. The initiative is the observation that in many high buildings such as

office buildings, commercial centres and housing blocks, electricity meters are often located near one another, sometimes even in a so-called meter room. In such cases, it is extremely efficient if one electricity meter reader can read many electricity meters. In the case of private houses, one electricity meter reader may still be able to read several electricity meters if they are located close to each other. Such an automatic electricity meter reading system is practical and efficient for big cities, especially those in populous Asia. The ability to read several electricity meters belonging to different customers by using a single electricity meter reader also overcomes the difficulty of reading electricity meters for those customers who do not have telephone lines.

Another important feature of the invention is that all the electricity meter readers are operated by the A.C. power lines passing through the electricity meters. Thus, no battery is required for the operation of the electricity meter readers.

This feature is based on the observation that when the A.C. power is off, the attached electricity meters become idle. Therefore there is no need to measure the amount of electricity consumed while the A.C. power is off, and the attached electricity meter readers can also be off. However, means has to be provided to ensure that an electricity meter reader is off only when all its associated electricity meters are off. A more detailed discussion of this feature is given below.

A further important feature of the invention is that an explicit and satisfactory solution is provided to the problem of reading an electricity meter. It is noted that, in use, a conventional electricity meter usually has

a visible revolving disc or a dial with a rotating pointer to indicate the amount of electricity being consumed. Based on this observation, a reflective optoelectronic sensor is mounted on the window of an electricity meter to sense the revolving disc or the rotating pointer. In this way, a meter reading can be taken without any modification of the electricity meter.

Another feature of this invention is that the functions of a microprocessor in each electricity meter reader are fully exploited to minimise the number of peripheral electronic components used. This can also enhance the reliability of the system because the amount of and frequency of communications between a microprocessor and its peripherals are also drastically reduced.

In one embodiment of the invention, a quasi-clock/calendar service is provided by a microprocessor. It is noted that in order for an electricity meter reader to provide the real time clock/calendar service, a battery and usually a clock/calendar IC chip is required, as is common with many prior art proposals. However, from the practical point of view, neither a utility company nor a customer would require an electricity meter reader to send the electricity meter data at a precisely fixed moment, such as at 1:12:20am on the 9th day of each month. Instead, an electricity meter reader is normally required to send the electricity meter data at any time on a day close to the pre-set day, e.g., a few days earlier or later than the pre-set day. Therefore, an internal timer within a microprocessor is programmed to emulate a clock/calendar when the A.C. power is on. This software clock/calendar will "freeze" when the A.C. power is off. Thus, the time base provided by the microprocessor is the actual time spent when the A.C. power is on, and will be called the

quasi-clock/calendar service instead of the real time clock/calendar service. As will be seen in later detailed description, this service is adequate for the purpose of automatically reading electricity meters.

No counter ICs are required in one embodiment of the present invention to count electric pulses which indicate the amount of electricity being consumed. Since the width of these pulses are fairly wide and their speed rather slow, the microprocessor is able to take over the task of counting all the pulses corresponding to the associated electricity meters.

Referring now to Figure 1, reference numeral 10 generally designates an automatic meter reading system embodying the present invention. The system 10 comprises: a plurality of electricity meter readers 19, each of which is linked to a single customer's telephone line 17, and is able to read a plurality (or set) of electricity meters 20 belonging to that customer and different customers in the neighbourhood; a small number of meter data receivers 14, each of which is linked to a telephone exchange 16 through a telephone line 15, and to a computer 12 through a multiplexer 13; and a multiplexer 13 and a computer 12.

All electricity meter readers are installed at the customers' residential or business sites, whilst the meter data receivers, the multiplexer and the computer are installed at an electricity control centre 11.

As stated earlier, one object of this invention is to seek to provide an extremely cost effective automatic electricity meter reading system which will replace human electricity meter readers. To achieve this goal, that is, to reduce the components in each electricity meter reader,

to cut down the number of electricity meter readers and to minimise the communication time between the electricity meter readers and the meter data readers, the proposed system provides only those functions directly related to electricity meter reading, and hence the operation of the system is relatively simple, as described in the following.

Referring now to Figure 2, reference numeral 30 is a block diagram of a preferred embodiment of an automatic electricity meter reader 19 of the system of Figure 1. The microprocessor is preferably an Intel 80C51, with 128 bytes internal random access memory (RAM), 4k bytes internal read only memory (ROM), 32 I/O lines, two 16 bits timers and a serial communication port. The electricity meter reader is able to read up to 9 electricity meters without using an I/O expander IC chip. An electricity meter reader capable of reading up to 29 electricity meters will be described later).

To ensure the proper operation of an electricity meter reader, it is wired in such a way that the A.C. power for the electricity meter reader must remain on as long as the A.C. power for one of its electricity meters is on. When an electricity meter reader is first installed or whenever its A.C. power supply recovers after a power outage, the D.C. power supply circuit 24 of the electricity meter reader provides two independent positive voltages Vcc and Vdd. After resetting, a microprocessor 21 in the electricity meter reader begins to run a programme stored in its internal ROM. It initialises itself by reading data from a pre-written non-volatile memory EEPROM 23 and storing the data in its internal RAM. Through its external interruption line 27 (INT1) and its interruption service subroutine (Fig. 14), the microprocessor begins to accumulate pulses generated from the electricity meter

interface circuit 26, these pulses being an indication of the amount of electricity being registered by each of the associated electricity meters. The microprocessor then converts these pulses into units (such as kilo-watt hours) suitable for billing to customers. Meanwhile, the microprocessor begins to emulate a clock/calendar by using one of its internal timer TØ. From the clock/calendar service (Figure 15), the microprocessor calculates the accumulated amount of time that the A.C. power has been on since the electricity meter data was previously sent to a meter data receiver in the electricity control centre. Whenever the A.C. power is off, the software clock/calendar will "freeze", and resume when the A.C. power is on.

When the accumulated days reaches the pre-set days, the microprocessor begins to prepare itself for sending the meter data to a meter data receiver 14 in the electricity control centre through the modem and telephone interface circuit 22 and a single customer's telephone line 17. It first sets up a re-communication flag and then checks whether or not the line is busy before going into an off-hook mode. Specifically, the microprocessor waits until the customer's telephone 18 (of Figure 1) is no longer occupying the line and then starts to dial the telephone number of the meter data receiver. If it cannot receive an identification code in a short while, say five seconds, it will go into on-hook mode, and wait for about two to three minutes before making another phone call to the meter data receiver 14. If, after dialing, the microprocessor does receive the correct identification code, it will send its own identification code, followed by the month in which data is being sent, the number of associated electricity meters, and the electricity meter data from each electricity meter. It then prepares itself for receiving the acknowledgement, the number of days until the next

electricity meter data is to be sent, and the new telephone number of the meter data receiver 14 if the old number is to be changed before the next dialing. If within five seconds, the electricity meter reader can receive the correct data from the meter data receiver, it will store the data in the respective RAM or EEPROM locations, clear the re-communication flag, and go into on-hook mode. Otherwise, it goes into on-hook mode, and will wait for about two to three minutes before making another phone call (Figure 12).

Whenever the A.C. power is off, the power off detector 25 sends a logic low level signal to the microprocessor through its external interruption lines 28 (INTØ), informing the microprocessor that the A.C. power is off. Because of a large capacitor 70 (of Figure 3), the D.C. power supply to the microprocessor remains on for a certain period of time even after the A.C. power is off, enabling the microprocessor to store all the necessary data into its EEPROM (Figure 13).

Referring back to Figure 1, at the electricity control centre 11, a small number of meter data receivers 14 are powered by an uninterrupted power supply (not shown) and operate constantly. Referring now to Figure 6, a meter data receiver 14 contains a microprocessor 150 which is preferably the same type as one used by an electricity meter reader (80C51). The microprocessor has 512k bytes external RAM, implemented by a SRAM 152 (IC No. 628512) and a latch 151 (IC No. 74LS373). Each associated electricity meter is allocated two bytes for storing temporarily either meter data (12 bits, representing up to 4095 kilo-watt hours) and the month (4 bits) or the month and the preferable call-in days (2 bytes). Therefore, each meter data receiver can handle up to 262,144 electricity meters.

Because the 80C51 has only 16 address lines, 3 I/O lines are used exclusively as additional address lines. Hence, while buses 155 and 156 each consists of 8 lines, bus 157 has 11 lines. The configuration and operation of the SRAM and the latch are standard.

Like an electricity meter reader, the microprocessor of a meter data receiver also uses its internal timer TØ to provide a software clock/calendar service. However, since the meter data receiver is operated by an uninterruptable power supply, no power failure should occur, and hence the software clock/calendar service actually provides the meter data receiver with a real time clock/calendar service. Normally, the microprocessor monitors through the modem and telephone interface circuit 153 and the communication interface circuit 154 if there is a phone call or if the computer 12 requires to communicate with it. Whenever the microprocessor detects a phone call through the modem and telephone interface, it goes into an off-hook mode and begins to send an identification code to the caller. It then waits to receive data from the caller. If it cannot receive the correct data within 5 seconds, it will go into an on-hook mode and wait for another phone call. If it does receive the correct data from an electricity meter reader, it will then store the electricity meter data in the proper locations in the SRAM 152. The microprocessor then calculates the number of days until this calling electricity meter reader should next send electricity meter data, and sends back an acknowledgement, and the number of days until the electricity meter reader should next call. In case the telephone number of the meter data receiver is going to change by the next time the electricity meter reader calls, the microprocessor also sends the new

telephone number to the calling electricity meter reader (Figure 17).

The next call-in time is calculated using the following principle. Each electricity meter reader is allocated a preferable date, say the 5th day of each month, when the electricity meter reader should send electricity meter data to the meter data receiver. This day is sent to the meter data receiver by the computer every time it receives the new electricity meter data, and stored in the same location where electricity meter data is kept before being sent to the computer. If the electricity meter reader sends meter data on the 7th day instead of the 5th day because of power failure, and the current month has 30 days, then the electricity meter reader should send meter data 28 days after this send day to compensate for the 2 days delay due to power failure. If from then on, there is no more power failure, the electricity meter reader will be able to send electricity meter data on the 5th day of every month. If there is a one day power failure occurring during this 28 day period, the electricity meter reader will send electricity meter data to the meter data receiver on the 6th, and this one day delay would be compensated for in the next month using the same strategy. Because power failure seldom happens for more than a few days in accumulation within one month, the computer and the electricity company is able to read automatically electricity meter data on a date close to the desirable day, and this method should be workable in practice.

When the microprocessor detects a signal from the computer requiring communication through the communication interface circuit, it first establishes a link with the computer, and then sends an identification code to the computer and waits for the replying identification code and

the control data. If the meter data receiver is installed for the first time, it has to receive firstly the necessary initialisation data from the computer, which includes a preferable call-in day for each electricity meter reader etc, and will send back an acknowledgement to the computer. The meter data receiver then transmits at high speed all newly read electricity meter data to the computer and waits to receive the preferable call-in days for those electricity meters. After receiving this data, it disconnects the link with the computer and waits for another phone call or a renewed communication requirement from the computer (Figure 18).

A computer 12 at the electricity control centre is designated to communicate with a small number of meter data receivers daily through a multiplexer 13 of Figure 1. Referring now to Figure 9, when the computer is required to communicate with one of the meter data receivers, the switch 251 in the multiplexer 13 is manually adjusted to establish a link between the computer and that meter data receiver. For example, if communication with meter data receiver number 1 is required, the switch is set to number 1. A request to send signal (RTS of the RS-232-C) from line 254 is then sent by the computer to line 255 of the meter data receiver No. 1, passing through the transmitter/receiver 252 (IC MAX232) and the buffer 253 (IC 74LS244). Once the computer receives an identification code from the meter data receiver No. 1 (the signal passing from line 257 (XD) to line 256 (RXD of the RS-232-C)), it sends back an identification code together with some useful control data such as the current time, the days of this month, and first installation information etc., (the signal passing through from line 258 (TXD of the RS-232-C) to line 259 (RD)). If the meter data receiver No. 1 is being installed for the first time, the computer proceeds

to send initialisation data to the meter data receiver, and clears an initialisation flag if sending successfully. The computer then waits for receiving the data from the newly read electricity meters from the meter data receiver, and sends back the preferable call-in days for those electricity meters before terminating the communication procedure. The computer also needs to store the newly read electricity meter data for the purpose of billing etc. When the computer is not required to communicate with any meter data receivers, the switch should be set to number 0, and the computer is now completely disconnected from all the meter data receivers, and can be used for other purposes (Figure 19).

Figures 10 to 15 are flow charts illustrating the operation of an electricity meter reader, while Figures 16 to 18 are flow charts illustrating the operation of a meter data receiver, and Figure 19 is a flow chart illustrating the operation of the computer when it is communicating with a meter data receiver.

It now remains to describe the circuitry of an electricity meter reader and that of a meter data receiver in detail.

Referring to Figure 3 reference numeral 24 designates a power supply circuit for an electricity meter reader. Two steps are taken to enhance the reliability of the electricity meter reader. One is to connect a filter/surge protector 72 to the primary winding of the transformer 78 to protect the electricity meter reader from external interference through the A.C. power line, which is linked to the electricity meter reader through lines 73. Another step is to provide two independent D.C. voltages Vcc and Vdd, both equal to +5V. Vcc is for all digital

circuits and for some analogue circuits directly linked to the microprocessor, while Vdd is used to isolate some peripheral components such as a relay from the microprocessor.

The function of the power off detector 25 is to signal the microprocessor as soon as the A.C. power is off, so that the microprocessor is able to store all the important data into the non-volatile memory EEPROM. Specifically, when the A.C. power is off, the voltage at point 74 becomes low and the transistor 75 is turned off. Because of the capacitor 70, voltage Vcc remains on for a short while. Hence, the voltage at point 76 becomes high and because of the inverter 79, line 28 outputs a logic low signal to the microprocessor to inform the microprocessor that the A.C. power is off. On the other hand, when the A.C., power is on, it is apparent that the voltage at line 28 will remain logic high.

Referring now to Figure 4, the electricity meter interface 26 consists of nine identical submodules 81 to 89, and five AND gates with open drains 91 to 95 (IC 74LS09). Each submodule is designated for reading one electricity meter and its function is described as follows.

Taking the submodule 81 for example, an infrared reflective optoelectronic sensor 96 is mounted on the surface of electricity meter 20, focusing on a revolving disc or on a rotating pointer of the meter 20, depending on the type of electricity meter to be mounted. The sensor is then connected to the electricity meter reader by wires 97. In normal operation, the sensor constantly picks up the colour mark difference and converts the signal to a voltage difference when the disc is revolving or when the pointer is rotating. This voltage difference is amplified by the

operational amplifier 98 and shaped into a square wave by a Schmitt trigger inverter 99 (IC 74LS14). This pulse series then serves as a clock for the JK flip/flop 100 (IC 74LS73), J1 being fixed at logic high and K1 logic low. When a falling edge occurs at $\overline{CLK1}$, line 41 ($\overline{Q1}$) becomes logic low. Consequently, the voltage at line 27 (INT1) becomes logic low, which interrupts the microprocessor. The microprocessor responds by checking its I/O lines 41 to 49 to determine which electricity meter sensor has generated the interruption request. Suppose that the voltage at line 41 is at logic low, the microprocessor will increase the corresponding pulse register by 1 and sends a logic low signal to line 31, which will clear the JK flip/flop 100. As a result, $\overline{Q1}$ becomes logic high, and the microprocessor returns to normal operation. Due to five AND gates 91 to 95, a low signal $\overline{Qi}$ (i = 1 to 9) output by any one of the submodules 81 to 89 is equally able to request the microprocessor for an interrupt service. Because of the high speed operation of the microprocessor and the relatively low speed of the pulses which are the same as the speed of the revolution of the disc or that of the rotation of the pointer, using the proposed method of this invention, the microprocessor has enough time to service at least several dozen electricity meters associated with it.

Referring to Figure 5, apart from a surge protector 121 and a line transformer 122, the modem and telephone interface 22 of an electricity meter reader consists of four submodules, namely, the telephone line status indicator 125, a modem IC chip 124, a hybrid circuit 123 and a telephone line switch 126. The function of each submodule is described as follows.

The function of the telephone line status indicator 125 is to tell the microprocessor whether the telephone line is occupied by the customer. Specifically, when the telephone line is occupied by the customer the absolute voltage between terminals "T" and "R" will drop from about 44V D.C. to about 2.5 to 12V D.C. Because of the bridge rectifier 129 and by selecting the resistors 133 and 134 to be 4M ohm and 1M ohm respectively, the voltage at point 130 will be below 3V D.C. Consequently, the comparator 135 will output a low voltage at point 131 and the voltage at the I/O line 57 will become high.

On the other hand, when the telephone is not occupied by the customer, the absolute voltage between terminals "T" and "R" will be equal to 44V D.C. Hence the voltage at point 130 will be greater than 5V. Consequently, the voltage at point 131 will become high and the voltage of the I/O line 57 will be low. Therefore, the microprocessor is able to know whether or not the telephone line is occupied by the customer by checking the status of the I/O line 57.

The function of the hybrid circuit 123 and the modem IC chip 124 is to convert analogue messages from the telephone line 17 to digital code for the microprocessor, and to transform digital code form the microprocessor to analogue messages through the telephone line 17. The modem IC chip is preferably MSM7512B by OKI. The microprocessor controls the mode of the modem IC through I/O lines 55 and 56, which are linked to pins MOD1 and RS of the modem IC. Lines 141 and 142 are linked to pins AO and AI. Lines 139 and 140 are linked to pins XD and RD. When the voltages at lines 55 and 56 become low, the modem IC chip 124 is in transmitting mode, and digital code from the microprocessor is passed to the modem chip through line 59, modulated by

the modem chip into analogue message, which is then transmitted to the hybrid circuit through line 141 and coupled to the telephone line 17 by the transformer 122.

On the other hand, when the voltages at lines 55 and 56 become high, the modem IC chip 124 is in receiving mode, and analogue messages from the telephone line are coupled by the transformer, transmitted through the hybrid circuit at line 142 into the modem IC. Analogue messages are then demodulated into digital code and transmitted to the microprocessor through line 60.

The function of the telephone line switch 126 is to connect the electricity meter reader to or to disconnect the electricity meter reader from the telephone line 17, and to pulse dial the appropriate telephone number of the meter data receiver. When the microprocessor sends a logic low signal to the I/O line 58, the voltage at point 144 becomes logic high, and so is point 145. Consequently, the transistor 146 is turned on, and the switch 148 of the relay 147 is closed. A low resistor is now connected between terminal "T" and "R" which emulates the off-hook mode of a telephone. On the other hand, when the microprocessor sends a logic high signal to the I/O line 143, the switch 148 of the relay 147 will be open, simulating the on-hook mode of a telephone.

When the "ON" and "OFF" time of the switch 148 of the relay 147 is controlled properly, the telephone line switch 126 can serve for the purpose of pulse dialing.

Comparing now Figure 7 to Figure 5, both modem and telephone interfaces, 152 of a meter data receiver, and 22 of an electricity meter reader, are almost the same in structure, except that the telephone line status indicator

125 of Figure 5 is replaced by the telephone ring detector 161 of Figure 7. The function of the telephone ring detector 161 is fairly simple, and is described as follows.

The main part of the telephone ring detector 161 is the ring detector IC 162, preferably TCM1520A by Texas Instruments. The telephone line terminal "R" is connected to a "AC INPUT" pin of the ring detector IC 162 via a capacitor 163 and a resistor 164, while the other terminal "T" is directly connected to another "AC INPUT" pin of the IC. When there is a "ring" signal coming from the telephone line 165, the ring detector IC 162 outputs a 5V at point 166 with respect to point 167. Consequently, the optoelectric coupler 168 is on, and the voltage at the I/O line 187 will be at logic low. The logic low signal at lien 187 tells the microprocessor that there is a telephone call.

Unlike the microprocessor of an electricity meter reader, the microprocessor of a meter data receiver has to communicate to the modem IC chip as well as to the computer through a multiplexer. Since the microprocessor 80C51 has only one serial communication port, a communication interface 154 of Figure 6 has to be provided to decide whether the microprocessor should communicate with a modem IC or with a computer.

Referring to Figure 8, the communication interface 154 consists mainly of a 3 state buffer IC, preferably 74LS244, and its function is to channel I/O lines 171 and 172, which are linked to pins XD and RD of the microprocessor 80C51, to lines 173 and 174 linking to the modem IC 175, or to lines 177 and 178 leading to the multiplexer of 13 of Figure 1. In normal operation, the microprocessor sends a logic high signal at I/O line 180.

Consequently, the voltage at line 181 is also high and lines 171 and 172 are disconnected from lines 177 and 178. Meanwhile, the voltage at line 182 is logic low, and lines 171 and 172 are connected to lines 173 and 174 respectively. On the other hand, when the microprocessor detects a logic low signal at line 179, which is sent by the computer through line 183 requesting to communicate with the microprocessor, it will then send a logic low signal at line 180. It can then be seen that I/O lines 171 and 172 will be switched from lines 173 and 174 to lines 177 and 178.

So far, a detailed description of a preferred embodiment of an automatic electricity meter reading system in accordance with the principles of the invention has been presented. In the preferred embodiment, an electricity meter reader is able to read up to nine electricity meters without using an I/O expander IC. As it has been pointed out earlier, because of the high speed operation of the microprocessor and the relatively low speed of the pulses generated from electricity meter sensors, and because of the method of responding to the pulses, a microprocessor is in fact able to read several dozen electricity meters. An electricity meter reader which is able to read up to twenty nine electricity meters is briefly described as follows.

It can be seen from the previous description and the drawings that 26 I/O lines of the microprocessor are used for general I/O purposes, among them 18 lines are for reading and controlling 9 electricity meters, each electricity meter requiring 2 I/O lines. If an I/O expander, preferably Intel 82C43, is used to expand I/O lines, then 6 I/O lines can be expanded to 16 I/O lines. If four I/O expanders 82C43 are used in another preferable embodiment of an electricity meter reader of the automatic

electricity meter reading system, then 26 I/O lines can be expanded into 66 I/O lines, among which 58 I/O lines will be available for reading and controlling electricity meters. If the microprocessor 80C51 is also replaced with a microprocessor 80C52, which has 256 bytes RAM, and 8k bytes ROM, then it can be seen that an electricity meter reader with four I/O expanders 82C43 will be able to read 29 electricity meters belonging to different customers in the neighbourhood using only one customer's telephone line. Since it is fairly straightforward to incorporate an I/O expander 82C43 with a microprocessor, a detailed description is omitted here.

Finally, although the meter reading system has been described thus far specifically with reference to electricity meters, the same principle can be applied to other utility meters such as gas or water meters. In the case of gas or water meters batteries have to be employed in order to maintain the normal operation of a meter reader when the A.C. power is off.

CLAIMS:

1. An automatic meter reading system comprising: a plurality of electricity meter readers, each of which is linked to a customer's telephone line, is able to read a plurality of electricity meters belonging to different customers in the neighbourhood, and is able to make a phone call and transmits periodically the meter reading to a remote meter data receiver, and to receive a next calling time from a remote meter data receiver during this telephone communication; one or more meter data receivers, each of which is able to receive a phone call and meter data from those associated electricity meter readers, and is able to transmit the received meter data daily to a computer through a multiplexer; a multiplexer which provides an interface between a computer and the meter data receivers; a computer which is able to receive meter data daily from one or more meter data receivers, and is able to store these data for the purpose of billing, printing and other processing.

2. An automatic meter reading system according to Claim 1, wherein each electricity meter reader is operated by mains power and does not require a battery to back up.

3. An automatic meter system according to Claim 1 or 2, wherein the structure and operation of the electricity meter is not affected by the installation and operation of an electricity meter reader and the meter data can be read as accurately as before an electricity meter reader is attached to it.

4. An automatic meter reading system according to any preceding claim, wherein the operation of an electricity meter reader linked to a customer's telephone line does not

interrupt the customer's normal telephone communication when the customer is occupying the telephone line and only occupies the linked telephone line for five to ten seconds at most.

5. An automatic meter reading system according to any preceding claim, wherein each electricity meter reader contains a microprocessor or which is able to provide a software clock/calendar service which outputs the accumulated amount of time for which mains power is on since the previous meter data was sent to the meter data receiver and the day upon which the next meter data is to be transmitted is based on a software clock/calendar service rather than a real time clock/calendar service.

6. An automatic meter reading system time according to any preceding claim, wherein the installation of an electricity meter sensor in an electricity meter reader for an electricity meter does not require any modification of the original electricity meter and the operation of the electricity meter sensor is not affected by the background light.

7. An automatic meter reading system according to any preceding claim wherein, the system is able to automatically read and transmit electricity meter data of those electricity meters belonging to customers who do not have telephone lines, if at least one customer in the vicinity has a telephone line.

8. An automatic meter reading system according to any preceding claim, wherein each electricity meter reader contains a microprocessor which is able to count pulses from a plurality of electricity meters and no external counter IC chips are required for counting pulses.

9. An automatic meter reading system comprising: a plurality of meter readers, each of which is linked to a customer's telephone line, is able to read a plurality of utility meters belonging to different customers in the neighbourhood, and is able to make a phone call and transmit periodically the meter readings to a remote meter data receiver, and to receive a next calling time from a remote meter data receiver during this telephone communication; one or more meter data receivers, each of which is able to receive a phone call and meter data from those associated meter readers, and is able to transmit the received meter data daily to a computer through a multiplexer; a multiplexer which provides an interface between a computer and the meter data receivers; a computer which is able to receive meter data daily from one or more meter data receivers, and is able to store these data for the purpose of billing, printing and other processing.

10. An automatic meter reading system for reading a plurality of meters comprising: a plurality of meter readers, each meter reader being provided with means for communicating via a single communication line with a control centre and means for sensing the meter readings of a set of the plurality of meters, the data read from the set of meters being communicated via the meter reader to the control centre.

11. An automatic meter reading system according to Claim 10, wherein the meter reader senses the meter reading of utility meters.

12. An automatic meter reading system according to Claim 10 or 11, wherein the meters of a number of separate customers are read by a single meter reader.

13. An automatic meter reading system according to any one of claims 10 to 12, wherein the means for sensing a meter reading comprises an optoelectronic sensor for providing a signal indicative of each revolution of a pointer or disc of a meter.

14. An automatic meter reading system according to Claim 13, wherein the meter reader is provided with a microprocessor for registering the signal from the sensor.

15. An automatic meter reading system according to any one of Claims 10 to 14, wherein the meter reader is powered by an electricity supply being metered by an electricity meter.

16. An automatic meter reading system according to Claim 15, wherein the main electricity supply powers the meter reader and the means for sensing the meter reading senses the meter reading of the electricity meter.

17. An automatic meter reading system according to any one of Claims 10 to 14, wherein the meter reader is provided with a battery power supply for powering the meter reader.

18. An automatic meter reading system substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

19. Any novel feature or combination of features disclosed herein.

Amendments to the claims have been filed as follows

1. An automatic meter reading system comprising: a plurality of electricity meter readers, each of which is linked to a customer's telephone line, is able to read a plurality of electricity meters belonging to different customers in the neighbourhood, and is able to make a phone call and transmits periodically the meter reading to a remote meter data receiver, and to receive a next calling time from a remote meter data receiver during this telephone communication; one or more meter data receivers, each of which is able to receive a phone call and meter data from those associated electricity meter readers, and is able to transmit the received meter data daily to a computer through a multiplexer; a multiplexer which provides an interface between a computer and the meter data receivers; a computer which is able to receive meter data daily from one or more meter data receivers, and is able to store these data for the purpose of billing, printing and other processing.

2. An automatic meter reading system according to Claim 1, wherein each electricity meter reader is operated by mains power and does not require a battery to back up.

3. An automatic meter system according to Claim 1 or 2, wherein the structure and operation of the electricity meter is not affected by the installation and operation of an electricity meter reader and the meter data can be read as accurately as before an electricity meter reader is attached to it.

4. An automatic meter reading system according to any preceding claim, wherein the operation of an electricity meter reader linked to a customer's telephone line does not

interrupt the customer's normal telephone communication when the customer is occupying the telephone line and only occupies the linked telephone line for five to ten seconds at most.

5. An automatic meter reading system according to any preceding claim, wherein each electricity meter reader contains a microprocessor or which is able to provide a software clock/calendar service which outputs the accumulated amount of time for which mains power is on since the previous meter data was sent to the meter data receiver and the day upon which the next meter data is to be transmitted is based on a software clock/calendar service rather than a real time clock/calendar service.

6. An automatic meter reading system time according to any preceding claim, wherein the installation of an electricity meter sensor in an electricity meter reader for an electricity meter does not require any modification of the original electricity meter and the operation of the electricity meter sensor is not affected by the background light.

7. An automatic meter reading system according to any preceding claim wherein, the system is able to automatically read and transmit electricity meter data of those electricity meters belonging to customers who do not have telephone lines, if at least one customer in the vicinity has a telephone line.

8. An automatic meter reading system according to any preceding claim, wherein each electricity meter reader contains a microprocessor which is able to count pulses from a plurality of electricity meters and no external counter IC chips are required for counting pulses.

9. An automatic meter reading system comprising: a plurality of meter readers, each of which is linked to a customer's telephone line, is able to read a plurality of utility meters belonging to different customers in the neighbourhood, and is able to make a phone call and transmit periodically the meter readings to a remote meter data receiver, and to receive a next calling time from a remote meter data receiver during this telephone communication; one or more meter data receivers, each of which is able to receive a phone call and meter data from those associated meter readers, and is able to transmit the received meter data daily to a computer through a multiplexer; a multiplexer which provides an interface between a computer and the meter data receivers; a computer which is able to receive meter data daily from one or more meter data receivers, and is able to store these data for the purpose of billing, printing and other processing.

10. An automatic meter reading system substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

11. Any novel feature or combination of features disclosed herein.

Patents Act 1977 Examiner's report to the Comptroller under Section 17 (The Search report)	Application number GB 9325982.8
Relevant Technical Fields (i) UK Cl (Ed.M) H4K (KOC) (ii) Int Cl (Ed.5) H04M (11/00)	Search Examiner KEN LONG
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Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii) ONLINE DATABASE: WPI	Documents considered relevant following a search in respect of Claims :-

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Category	Identity of document and relevant passages		Relevant to claim(s)
Y	GB 2099260 A	(TIMEX) See particularly page 3 lines 6-28, page 4 lines 14-19 and 29-31 and page 7 lines 17-19	1, 3-6 and 9
Y	EP 0013982 A1	(METRETEK) See particularly page 2 line 25 to page 3 line 10, page 7 lines 1-13 and 25-27 and page 12 line 30 to page 13 line 6	1, 3-6 and 9
X	WO 87/07993 A1	(BADGER METER) See particularly page 11 lines 14-29, page 12 lines 15-30 and page 13 lines 22-32	1, 3, 4, 6 and 9
Y	WO 85/01852 A1	(TELDATA II) See particularly page 6 lines 14 to page 7 line 17	1, 3-6, 9
X	US 4866761	(BADGER METER) See particularly column 3 lines 17-28, column 6 line 60 to column 7 line 7 and column 7 lines 33-49	1 and 9

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